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Electricity generation from the first wind farm situated at Ras Ghareb, Egypt

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ABSTRACT

Egypt is one of the Red Sea and Mediterranean countries having windy enough areas, in particular along the coasts. The coastal location Ras Ghareb on the Red Sea has been investigated in order to know the wind power density available for electricity generation. To account for the wind potential variations with height, a new simple estimating procedure was introduced. This study has explicitly demonstrated the presence of high wind power density nearly 900 kW/m^2 per year at 100 m of altitude for this region. Indeed, the seasonal wind powers available are comparable to and sometimes higher than the power density in many European cities for wind electricity applications like Vindeby (Denmark) and also America.

New technical analysis for wind turbine characteristics have been made using three types of commercial wind turbines possessing the same rotor diameter and rated power to choice the best wind machine suitable for Ras Ghareb station. As per the decreasing the cut-in wind speed for the wind turbine used, the availability factor increases for a given generator. That it could produce more energy output throughout the year for the location.

The aim of this research, was to predict the electrical energy production with the cost analysis of a wind farm 150 MW total power installed at Ras Ghareb area using 100 wind turbines model (*Repower MD 77*) with 1.5 MW rated power. Additionally, this paper developed the methodology for estimating the price of each kWh electricity from the wind farms. Results show that this wind park will produce maximum energy of 716 GWh/year. The expected specific cost equal to 1.5 €cent/kWh is still less than and very competitive price with that produced from the wind farms in Great Britain and Germany and at the international markets of wind power. The important result derived from this study encourages several wind parks with hundreds of megawatts can be constructed at Ras Ghareb region.

Contents

1. Introduction

Wind farms have been used for centuries in remote and rural areas for electricity generation and water pumping. Desert regions could provide space for large-scale utilization of wind energy, provided they are favoured by a healthy wind climate and situated not too far from places where power is demand. One of such region is the Gulf of Suez and northern Red Sea between the Eastern Desert and Sinai Peninsula in Egypt. From the geophysics point, Gulf of Suez at our country has many cities, these included the most populated and industrial regions for oil and petroleum products. This part in Egypt also has a huge amount of electricity can be generated by the wind, due to several good factors (i.e. technical and environmental). If a large amount of electricity were generated from wind during the year there, this would reduce the use of fossil fuel in electricity generation and hence the emission of greenhouse (CO_2) and thereby protecting our environment from such pollutants at this important area of the land [1–7]. Also, Egypt in particular as the Egyptian economy is heavily dependent on exporting energy. Egypt's energy resources are limited in oil and petroleum products but it has large reserves of natural gas and its export is an

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Table 1
Measured and calculated mean monthly wind speeds for the years 2000–2005 of Ras Ghareb station at 24.5 and 100 m, respectively.

Mean wind speed	Month												Annual mean
	Jan.	*Feb.*	*Mar.*	*Apr.*	*May.*	*Jun.*	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	
$V_{24.5}$	7.5	7.8	9.3	9.7	10.3	12.0	11.1	11.7	11.4	10.0	7.8	7.7	9.8
V_{100}	9.7	10.0	12.0	12.5	13.3	15.5	14.3	15.1	14.7	12.9	10.0	9.9	12.5

important contributor to the economy. On the other side, Egypt has renewable energy resources in large measure such as solar, geothermal and wind. Of these resources it is wind which seems most suitable for electricity generation. There is no industrial manufacture of wind Turbines in Egypt so equipment and expertise must be imported from other countries. Supported by a sustained governmental commitment and a fruitful international cooperation a series of large-scale wind energy projects has been constructed, at the Gulf of Suez with total capacity of 550 MW, at Zafarana and Hurghada areas. Recently, Egypt has adopted ambitious plan to cover 20% of the generated electricity by renewable energy by 2020, including a 12% contribution from wind energy, translating more than 7000 MW grid-connected wind farms. Such plan gives a room enough to the private investment to play the major role in realizing this goal [26–30].

Possible wind energy projects thus face a basic lack of knowledge of the wind resource as well as a large-than-usual uncertainly in the siting process. The present study is based on measurements of wind speed and direction taken from 2000 to 2005 at meteorological stations along the Gulf of Suez and the northern Red Sea. The 25-m masts were erected for the wind study and also provide information on other climate statistics, some of which will be important for wind energy engineers to design and implementation of future wind energy projects in this area. In our previous review [1] we presented the first detailed wind data analysis and wind energy potential at Ras Ghareb area, an important city for oil on the west coast of the Gulf of Suez and Red Sea in Egypt. It is appear from the research that this location has been explored for generating the electricity. Where it is comparable to and sometimes higher than the power density in European countries, America and Canada.

To achieve this goal, this article studies the wind power applications and the cost of each kilowatt hour of electricity produced from a wind farm of 150 MW total power considered at Ras Ghareb region by a new developing methodology. Throughout this economic analysis, the results compared with the retail tariff from WECS in the UK and Germany, also with the price of electricity produced from different systems actually used in Egypt.

2. Estimation of wind potential for electricity production

Wind speed is an important factor in the process of assessing the wind energy potentialities of a site or an area especially as the power in the wind is proportional to the cube of its velocity. Additionally, when a mass of air moves with a certain speed in a particular direction, wind power is being produced. A conversion system (machine) has to be placed in the wind path to extract some of the power in the wind. The power gained by the machine is that lost by the wind except for frictional and mechanical losses [8]. For Ras Ghareb station, the data base of wind speed and direction were measured and investigated in Ref. [1] at 24.5 m altitude.

The energy yield from wind machines is highly dependent on the wind speed at hub height. Usually, the wind speed measurements are made at heights much lower than the hub heights of modern wind machines. For energy estimations from such machines, the wind speed at hub height is calculated using 1/7th wind power law which may underestimate or overestimate the wind speed which ultimately will provide wrong estimated of energy. Hence, wind shear coefficient for actual location of wind machine siting should be used [9]. At the beginning, the vertical extrapolation of wind speed and mean wind power density has been subject to numerous investigations in recent years. The common expression for calculating the wind speed at any height (h) based on the measured wind speed stated in many references called Hellman's exponential law [5]. On the other hand, Justus [10] recommended usage Hellman's equation in the range of heights (0–100 m) above the ground level under some conditions. Then, as recommended at the paper [1], we will use the wind shear coefficient of 0.18 which must be applied to calculate the wind speed at different heights if wind measurements are available at one height at Ras Ghareb area. According to last description, the expected wind machine has a tower height of 100 m at least, so the wind speeds for Ras Ghareb area are adjusted at this height. The results are given in Table 1 beside the measured values of mean monthly wind speeds for the station.

Secondly, since the power density of the wind above the ground level will mainly affected by the increase in wind speed with height, where the effect of height on air density for the elevations under consideration is negligible. Hence, a new simple estimating procedure can be introduced to estimate the monthly wind power density at any desired height by the following formula:

$$P_{h(mo.)} = 0.72 P_{10(mo.)} \left(\frac{h}{10}\right)^{3\alpha} (\mathrm{kW/m^2 \cdot month}) \quad (1)$$

For this analysis we use, $\alpha = 0.18$, as mentioned above for Ras Ghareb region.

Finally, due to the common heights of large wind turbines at the world markets are found to be from 100 to 160 m above the ground level. Thus, by using the corrected monthly values of available wind power at 10 m height from the research [1] and then by substituting these values in the Eq. (1), we obtain the annual and monthly wind power density at the height of 100 m. Table 2 is prepared and the result is plotted in Fig. 1. From these table and figure, we can derive the following:

(1) The monthly average of wind power density is seen to vary between 389 and 1560 ($\mathrm{kW/m^2}$ month), with the annual mean value equal to 898 $\mathrm{kW/m^2}$. Where the peak of the expected

Table 2
Available corrected mean monthly wind power density at 10 and 100 m heights, respectively, beside the monthly wind turbine efficiency values of the three identical wind machines considered at Ras Ghareb area.

Month	$\mathbf{P_{10}}$ ($\mathrm{W/m^2}$)	$\mathbf{P_{100}}$ ($\mathrm{kW/m^2}$ month)	η (%)
Jan.	156	389	60
Feb.	170	424	55
Mar.	291	726	32
Apr.	338	844	27
May.	402	1004	23
Jun.	625	1560	15
Jul.	506	1263	18
Aug.	589	1470	16
Sep.	538	1343	17
Oct.	363	906	26
Nov.	170	424	55
Dec.	170	424	55
Annual	360	898	33

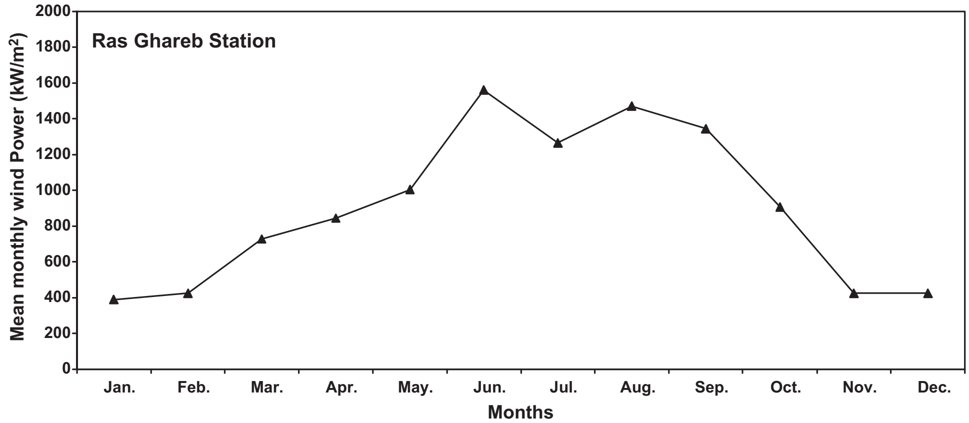


Fig. 1. Monthly variation of wind power density at 100 m height.

wind power appears from March to October as a result of the increase in its wind speeds values at these months over the year.

(2) An exhaustive view, the absolute minimum of $\mathbf{P_{100}}$ was observed at January 389 kW/m^2 followed by February and December 424 kW/m^2. However, the absolute maximum highest expected wind power, $\mathbf{P_{100}}$, was found at June 1560 kW/m^2 followed by 1470 kW/m^2 recorded at August, which are an international high values and as high as the wind potential in many European cities for wind electricity applications like Vindeby (Denmark).

(3) From Table 2, also we can derive Fig. 2 that is draw the expected wind power at 100 m hub height for Ras Ghareb station on the seasonal scale. One can notice that the wind power density is higher during the Summer months. Indeed, the wind power available at Summer season only is 4293 kW/m^2, which is 3.5 times greater than the wind density available at Winter months and therefore, it is more 1.5 times the wind power potential at Spring or Autumn periods.

3. Availability factor and the choice of the wind turbine

Efforts to resolve the problem of choice the best wind machine for each location which has been explored for generating the electricity and increasing the energy output, has focused on three main approaches. The first approach is "Capacity Factor". Chang et al. [11] concluded that for a very large rotor together with a very small generator, a wind turbine run at full capacity and thus achieve a very high capacity factor. But it could produce very little electricity, resulting in low wind turbine efficiency. In such a situation, considering only capacity factor cannot provide overall information on wind turbine characteristics. Another way of stating the annual energy output from a wind turbine is look to at the capacity factor for the turbine in its particular location. Capacity is the actual annual energy output dividing by the theoretical maximum output, if the machine were running at its rated (maximum) power during all of the 8760 h of the year. Capacity factors may theoretically vary from 0 to 100%, but in practice they will usually range from 20 to 70% [12]. In this study we can determine the CF for any wind turbine by using its equation as introduced earlier at the Ref. [6].

On the other side the second approach will be "Turbine Efficiency". Whereas the value of 59.3% represents the *Betz* efficiency or maximum theoretical efficiency of a turbine rotor [13,14]. Since the wind energy available in the wind cannot be completely extracted by any wind turbine. In order to provide practical estimations: the wind turbine efficiency η, defined as the ratio between recoverable energy on the aerogenerator and available energy at *Betz* limit, is meaningful for evaluating turbine performance. This is done by applying our formula which is stated in Ref.[3] to estimate the monthly wind turbine efficiency as follow:

$$\eta_{\text{monthly}} = \frac{720}{S_a}\frac{P_r}{P_{h\,(\text{mo.})}} \tag{2}$$

where P_r is the rated power of the chosen wind turbine kW, S_a is the rotor swept area (m^2).

Finally, "Availability Factor" is the third approach. It is defined as a measurement of the operation percentage of a wind turbine. Also, it refers to the percentage of time that a wind turbine is operating, which depends on wind turbine characteristics and wind energy potential [15,16]. Furthermore, to understand in depth the "Availability Factor" of a given generator, that is the most important wind turbine characteristics which can give more information and right

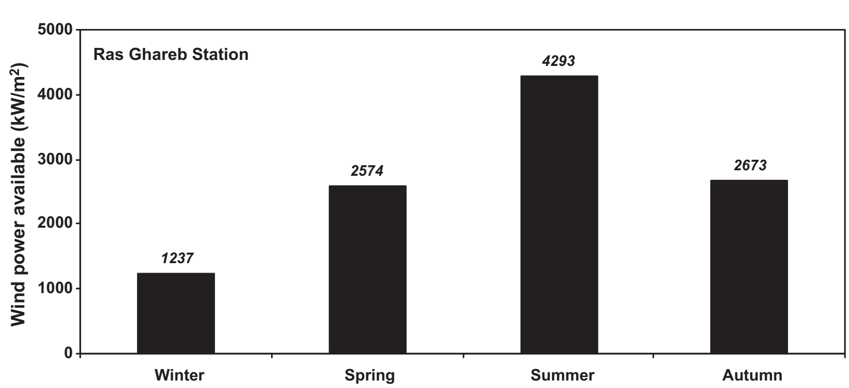


Fig. 2. Expected seasonally power potential at 100 m hub height over the year.

Table 3
Turbine characteristics for the wind machines used in the analysis and the yearly energy output estimated by WASP for Ras Ghareb station.

Operating data	Repower MD 77	Fuhrlander FL MD 77	Nordex S 77
E_{out} (kW/h/year)	7,614,127.0	7,578,928.0	7,532,868.0
Capacity Factor	57%	57%	57%
Rated Power (P_r)	1500 kW	1500 kW	1500 kW
Hub height	100 m	100 m	100 m
Rotor diameter	77 m	77 m	77 m
Swept area	4657 m^2	4657 m^2	4657 m^2
Number of blades	3	3	3
Cut-in wind speed (V_{cj})	3 m/s	4 m/s	4 m/s
Rated wind speed (V_r)	13 m/s	12 m/s	13 m/s
Cut-off wind speed (V_{co})	20 m/s	20 m/s	20 m/s
Expected life (years)	20	20	20
Price/Euro	1,700,000	1,700,000	1,300,000

direction to choice the best wind machine suitable at the world markets for Ras Ghareb area.

Hence, three different types of commercial wind turbines possessing the same rated power 1500 kW have been chosen for this study. The technical data for the machines are prepared in Table 3. The information given Table 3 is obtained from references [17–19] for wind turbines: ***Repower MD 77***, ***Fuhrländer FL MD 77***, and ***Nordex S 77***, respectively. These horizontal axis turbines are composed of three blades with diameter of 77 m and their swept area are the same 4657 m^2. To simplify calculations and exposition, we choose different models of wind turbines with the same hub height 100 m. These machines have a minimum speed, called the "cut-in" speed, below which they do not produce power. The cut-in speed for wind turbine ***Repower MD 77*** is 3 m/s while for other two 4 m/s. They also have a maximum or "cut-out" speed which they shut down for self-protection, also not producing power. The cut-out speed is 20 m/s for all three machines. Their rated power for wind speeds = 13 m/s for ***Repower MD 77*** and ***Nordex S 77*** and is 12 m/s for ***Fuhrländer FL MD 77***. The expected life of the machines and the other characteristics are also included in Table 3.

Consequently, to completely describe wind turbine characteristics, the capacity factor, turbine efficiency, and the availability factor of a specific wind turbine should be considered together. So, the capacity factor and the wind turbine efficiency, for each type of wind machine is assumed to be located at Ras Ghareb station, are investigated and the results reported in Tables 2 and 3 accompanied with Fig. 3. The important characteristics which we note from the tables and figure are that: the three different wind turbines have nearly the same annual values of capacity factor (57%) if worked at Ras Ghareb region because they have the same rated power 1.5 MW. And the monthly and annual values of turbine efficiency also are equal for them. This is due to their rotor swept area are identical value 4657 m^2. An integral view of Fig. 3 gives the following findings:

(1) An opposite monthly trend can be observed, where from March to October the monthly wind speeds have high values, see Table 1. But all wind machines have less wind turbine efficiency values than the low wind speeds values measured from November to February over the year. This is because these turbines are operating a constant rated power at wind speeds between the rated and cut-off wind speed.
(2) Meanwhile, the energy available in the wind is still proportional to the cubic of wind speed. The wind turbine efficiency is thus decreasing as the wind speed probability distributed between the rated speed and cut-off speed is increasing.

On the contrary, by using the power curve for every turbine together with WASP program and the values of mean wind speeds at Table 1. The average annual energy generated by the three commercial machines can be estimated for Ras Ghareb station and the results are presented in Table 3. The wind turbines can generate electrical energy amounting to 7,614,127 kWh, 7,578,928 kWh, and 7,532,868 kWh per year, respectively. They are plotted as solid lines in Fig. 4. These curves show how much energy output is produced by every wind machine. It is possible conclude the following:

(1) The yearly energy generated by the wind turbine ***Repower MD 77*** is relatively greater than the energy produced from the wind machines ***Fuhrländer FL MD 77***, and ***Nordex S 77***. This happens because the cut-in speed is 3 m/s for ***Repower MD 77*** while for other two 4 m/s, which makes the wind turbine of producing more energy. Since the electrical energy from the wind turbine is governed by the design features of wind turbine such as cut-in speed, that is the minimum wind speed required to start delivering useful power [20,21]. In addition, it is observed that the wind speed remained above 3 m/s for almost 4% of the times (frequency of occurrence) over the whole year which is a positive point at Ras Ghareb station, i.e. the wind data at 100 m above the ground, theoretically, assures availability of the wind during which WECS (***Repower MD 77***) can generate power.
(2) This is means that in general, the availability factor increases as the decrease of the cut-in wind speed of a wind turbine. Most modern wind turbines have high values of availability factor.
(3) Similarly, if we take 100 machines as an example from every model to contribute a wind park, the generated energy difference between ***Repower MD 77*** and ***Fuhrländer FL MD 77*** as a

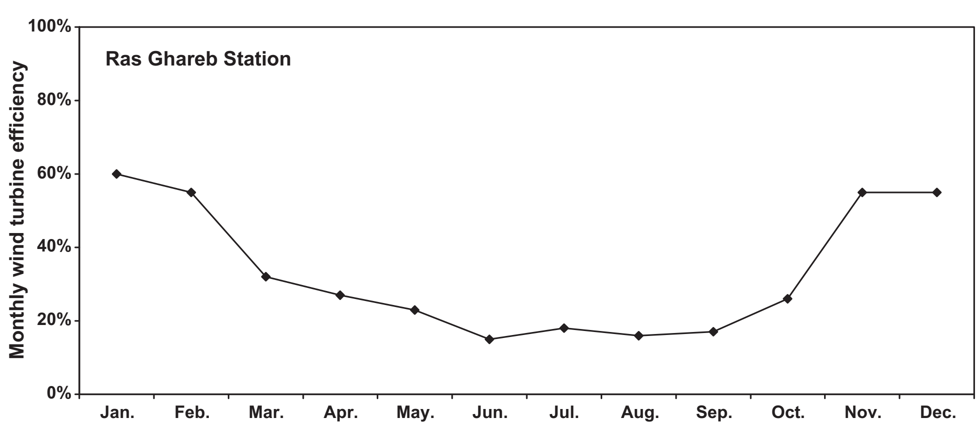


Fig. 3. Monthly variation of wind turbine efficiency for the three commercial wind turbines have the same rotor swept area and rated power.

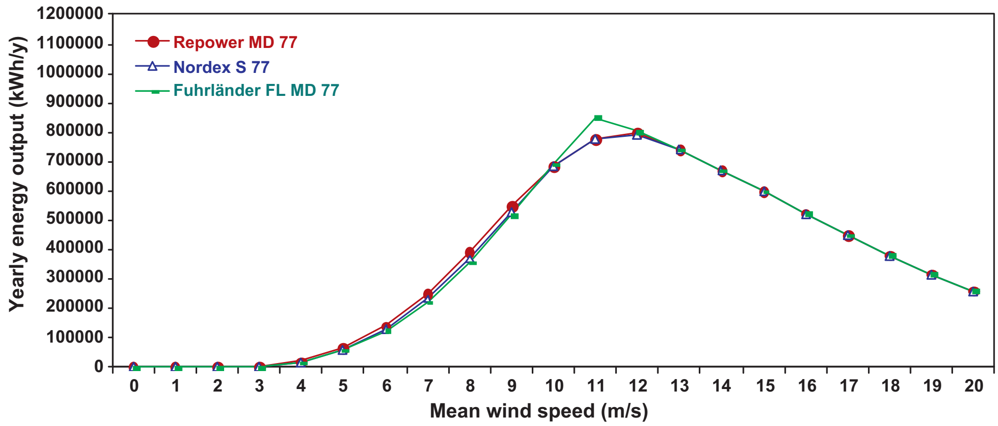


Fig. 4. The average annual energy generated by the three different wind turbines considered at Ras Ghareb location.

farm will be **3** GWh/year. And the gain output of energy difference between ***Repower MD 77*** and ***Nordex S 77*** is about **8** GWh/year.

(4) Hence, we choose and recommend the commercial wind turbine model ***Repower MD 77***, with hub height 100 m, as the most suitable wind turbine that it could produce more energy output throughout the year- at Ras Ghareb area to establishment a wind farm with 150 MW total power.

4. Generation cost from the wind farm

The use of wind as an energy source requires that the cost of energy from the wind turbines be competitive with the cost of energy from conventional sources. Ras Ghareb location was chosen to install 150 MW-wind farm consisting of 100 commercial wind turbine model (***Repower MD 77***), each of them having rated power 1500 kW, and its technical properties at Table 3. These turbines must be locate 150 m distance apart each other to prevent energy production loses of park effect. Additionally, the direction of the wind statistics play an important role in the optimal positioning of a wind park in a given area. At Ras Ghareb station, the prevailing wind come mainly from the north-northwest direction and is ideally suited for wind turbines siting on the wind farm project [1], which will be developed on the campus area. On the other side, in recent years the method of the present value of money (PVC) is employed, to estimate the cost of a kilowatt-hour produced by the chosen wind energy conversion system. Similar procedure and assumptions used by many authors [22–24]. Where there are many factors that should be considered when calculating the cost of energy generated by a wind farm for a specific site.

In this section, we present a developing methodology for estimate the cost of each kWh of electricity producing from a wind farm consisting of 100 machines located at Ras Ghareb region. This will be done by a simple estimating procedure can be introduced by the following new formula:

$$\mathbf{PVC} = \boldsymbol{I} + \mathbf{MH} + C_{\mathrm{omr}}\left[\frac{1+i}{r-i}\right] \times \left[1-\left(\frac{1+i}{1+r}\right)^{t}\right] - S\left(\frac{1+i}{1+r}\right)^{t} \quad (3)$$

where

(1) investment (**I**) includes the machine price plus its 20% for the civil work and other connections.

(2) major overhaul (**MH**) is a fixed value taken to be 2% of (**I**), it was used during the calculations.

(3) operation, maintenance and repair cost ($\mathbf{C}_{\boldsymbol{omr}}$) was considered to be 25% of the annual cost of the turbine (machine price/life time).

Table 4
The cost of kWh of electricity generated from different systems actually used in Egypt [4].

System	Cost ($ cent/kWh)
1 WEC system	1.8
2 Combined cycle system	2.4
3 Conventional steam-fuel oil fired	5.4
4 Gas turbine diesel oil fired	5.4
5 Photovoltaic system	14.0

(4) the interest rate (**r**) and inflation rate (**i**) were taken to be 15% and 12%, respectively.

(5) the life time of the wind machine (**t**) was assumed to be 20 years.

(6) scrap value (**S**) was taken to be 10% of the turbine price and civil work.

As is evident from Eq. (3), this additional term (**MH**) refers to the major overhaul should be assumed due to the wind farm have a huge number of wind turbines up to 100 machines. And after about 10 years this assumption must be considered for PVC value.

The price of the wind turbine from Table 3 and other assumptions were substituted at Eq. (3), and in case of the wind farm, the capital investment, **I**, is taken as the number of units multiplied by the unit price, from which the developed present value of money was obtained as follow:

$$\mathbf{PVC} = 228, 631, 390$$

Then, calculated energy production of located 100 turbines with total capacity of 150 MW was 761,412,700 kWh/year. So, the cost per kWh = [(228,631,390)/(20 × 761,412,700)] = ***1.5 €cent***. Indeed, installing wind farm at this site to generate electricity is economically feasible.

Furthermore, by comparing the result of expected cost of electricity generation from this assumed wind park at Ras Ghareb area, we found that it is below the cost of 1 kWh produced by the Egyptian Electricity Authority using diesel oil, natural gas and photovoltaic system as shown in Table 4, Generally, WEC systems is the most economic technology for electricity generation in Egypt.

Therefore, additional cost comparison for our result of generating wind energy with the retail tariff from WECS in the UK and Germany indicates that: for the future in Great Britain, the price of energy delivered from wind turbine will decrease linearly to reach 2.7 p/kWh in 2020. However, the tariff from wind energy in German electricity prices was subsequently revised to 8.7 €cent/kWh for 5 years and 5.6 €cent/kWh for the following 15 years between 2002 and 2022 [25].

Hence, these comparisons encourage the construction of several wind farms at Ras Ghareb City. Where the expected specific cost for electricity generation equal to 1.5 €cent/kWh, which is very competitive price compared to the actual tariff system at the national market of wind energy.

5. Conclusion

From this study we reach to the following main conclusions:

(1) Ras Ghareb City on the west coast of the Red Sea in Egypt has strong wind potential at 100 m of altitude and ideally suited for large wind turbines siting. The power density from wind can reach about 900 kW/m^2 per year. The peak of the wind power appears from March to October, where the maximum value of $\mathbf{P_{100}}$, was found at June 1560 kW/m^2 followed by 1470 kW/m^2 recorded at August, which are comparable to and sometimes higher than the power density in many European cities for wind electricity applications like Vindeby (Denmark) and also America or Canada.

(2) From the seasonal view, the wind power potential is higher during the Summer months. Indeed, the wind power available at Summer period only is 4293 kW/m^2, which is 3.5 times greater than the wind density available at Winter months and therefore, it is more 1.5 times the wind power density at Spring or Autumn seasons.

(3) The availability factor of a given generator, is the most important wind turbine characteristics which can give more information and right direction to choice the best wind machine suitable for the location explored for electricity generation. Moreover, the availability factor increases as the decrease of the cut-in wind speed of a wind turbine.

(4) For the investigated station with three different commercial wind machines, we recommend the wind turbine model ***Repower MD 77***, with rated power 1.5 MW at 100 m hub height, as the most suitable wind turbine -that it could produce more energy output over the year at Ras Ghareb area.

(5) The evaluation method (methodology) to estimate the price of each kWh electricity from the wind farm has been developed by an additional term (**MH**) refers to the major overhaul which should be considered for PVC value of the wind farm that have a huge number of wind turbines.

(6) It is possible to establish at Ras Ghareb station a wind farm with 150 MW total power, consisting of 100 machines model ***Repower MD 77*** which produced energy output in the range of 761,412 MWh/year. The electricity generation cost is estimated to be ***1.5 €cent/kWh***. An appropriate price should see the wind farm attain economic viability.

(7) The important result derived from this research that several wind parks with hundreds of megawatts of wind turbine capacity can be installed at Ras Ghareb area along the Gulf of Suez in Egypt. Where the expected cost of electricity generation was found to be less than and very competitive with the cost of kilowatt–hour produced from the wind farms in Great Britain and Germany and from different systems actually used in Egypt.

References

[1] Ahmed Shata A. Investigation of wind characteristics and wind energy potential at Ras Ghareb, Egypt. Renewable and Sustainable Energy Reviews 2011;15:2750–5.
[2] Ahmed Shata A. Analysis of electrical power form the wind farm sitting on the Nile River of Aswan, Egypt. Renewable and Sustainable Energy Reviews 2011;15:1637–45.
[3] Ahmed Shata A. Wind energy as a potential generation source at Ras Benas, Egypt. Renewable and Sustainable Energy Reviews 2010;14:2167–73.
[4] Ahmed Shata AS. Theoretical investigation and mathematical modelling of a wind energy system-Case study for Mediterranean and Red Sea. Ph.D. thesis submitted to Faculty of Electrical Engineering and Computer Science, Berlin University of Technology, Germany; June 2008.
[5] Ahmed Shata AS, Hanitsch R. Electricity generation and wind potential assessment at Hurghada, Egypt. Renewable Energy 2008;33:141–8.
[6] Ahmed Shata AS, Hanitsch R. The potential of electricity generation on the east coast of Red Sea in Egypt. Renewable Energy 2006;31:1597–615.
[7] Mortensen NG, Youssef LG. Wind atlas for Egypt. Measurements and modeling 1991–2005. Risø National Laboratory, Roskilde, New and Renewable Energy Authority, and Egyptian Meteorological Authority, Cario; December 2005, ISBN 87-550-3493-4.
[8] Radhwan AM. Wind energy applications in remote areas of Saudi Arabia. International Journal of Ambient Energy 1994;15(3):123–30.
[9] Rehman S, Al-Abbadi NM. Wind shear coefficients and energy yield for Dhahran, Saudi Arabia. Renewable Energy 2007;32:738–49.
[10] Justus CG, Amir Mikhail. Height variation of wind speed and wind distributions statistics. Geophysical Research Letters 1976;3(5):261–4.
[11] Chang T-J, Wu Y-T, Hsu H-Y, Chu C-R, Liao C-M. Assessment of wind characteristics and wind turbine characteristics in Taiwan. Renewable Energy 2003;28:851–71.
[12] Teetz HW, Harms TM, von Backström TW. Assessment of the wind power potential at SANAE IV base, Antarctica: a technical and economic feasibility study. Renewable Energy 2003;28:2037–61.
[13] Masters GM. Renewable and efficient electric power systems. New York: Wiley-Interscience; 2004.
[14] Pimenta F, Kempton W, Garvine R. Combining meteorological stations and satellite data to evaluate the offshore wind power resource of Southeastern Brazil. Renewable Energy 2008;33:2375–87.
[15] Jangamshetti SH, Rau VG. Site matching of wind turbine generators: a case study. IEEE Transactions on Energy Conversion 1999;14(4):1537–43.
[16] Balouktsis A, Chassapis D, Karapantsios TD. A nomogram method for estimating the energy produced by wind turbine generators. Solar Energy 2002;72(3):251–9.
[17] http://www.repower.de.
[18] http://www.fuhrlaender.de.
[19] http://www.nordex-online.com.
[20] Manwell JF, McGowan JG, Rogers AL. Wind energy explained: theory, design and application. New York: Wiley; 2002.
[21] Mabel MC, Fernandez E. Analysis of wind power generation and prediction using ANN: a case study. Renewable Energy 2008;33:986–92.
[22] Alnaser WE. Assessment of the possibility of using three types of wind turbine in Bahrain. Renewable Energy 1993;3(2/3):179–84.
[23] Rehman S, Halawani TO, Mohandes M. Wind power cost assessment at twenty locations in the kingdom of Saudi Arabia. Renewable Energy 2003;28: 573–83.
[24] Gökçek M, Genç MS. Evaluation of electricity generation and energy cost of wind energy conversion systems (WECSs) in Central Turkey. Applied Energy 2009;86:2731–9.
[25] Butler L, Neuhoff K. Comparison of feed-in tariff, quota and auction mechanisms to support wind power development. Renewable Energy 2008;33:1854–67.
[26] El-Sayed MAH. Substitution potential of wind energy in Egypt. Energy Policy 2002;30:681–7.
[27] Saleh LA. Impact of the integration of the 63 MW wind-farm in Zafarana Egypt on the unified power-grid. Applied Energy 2003;74:247–60.
[28] Saleh L. National programs for wind energy utilization in Egypt. Renewable Energy 1994;28:580–2.
[29] Ahmed Shata AS, Hanitsch R. Applications of electricity generation on the western coast of the Mediterranean Sea in Egypt. International Journal of Ambient Energy 2008;29:3544.
[30] Abul'Wafa AR. Matching wind turbine generators with wind regime in Egypt. Electric Power Systems Research 2011;81:894–8.